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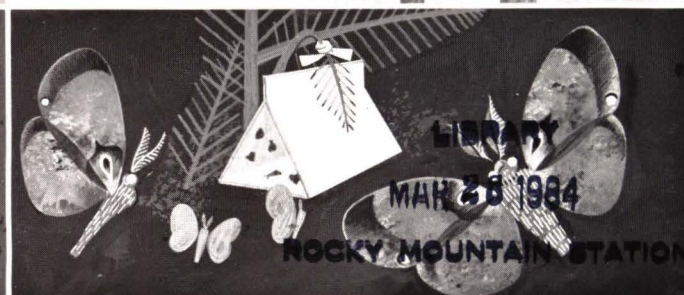
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ROOT DISEASE-CAUSED LOSSES IN THE COMMERCIAL CONIFEROUS FORESTS OF THE WESTERN UNITED STATES 1/



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ROOT DISEASE-CAUSED LOSSES IN THE COMMERCIAL
CONIFEROUS FORESTS OF THE WESTERN UNITED STATES 1/

Compiled by

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ABSTRACT

Estimates of cubic-foot volume loss caused by root disease mortality in the forests west of the Great Plains are provided. The average annual loss in commercial forest lands of all ownerships is estimated to be 237.4 million cubic feet and is expected to increase in future years. Root diseases are responsible for approximately 18 percent of the total tree mortality in the western United States. Five root diseases are responsible for most of this loss. Root diseases decrease timber production, increase management costs, adversely affect other resources and predispose host trees to more frequent and damaging insect outbreaks.

INTRODUCTION

Root diseases are one of the most damaging classes of forest tree diseases in the western United States. All Regions, States, forest types, and tree species are adversely affected by one or more kinds of root disease. These root diseases cause economic losses by killing trees, decaying wood, slowing tree growth, predisposing trees to other harmful pests, causing trees to fail and fall over, and preventing reforestation from occurring.

Although root diseases have been considered to be an important cause of volume loss, there has been little information and data on a national basis to support this contention until recently. During the last decade we have gained a better understanding of root diseases and their effects, and have accumulated some loss data. Consequently, we are now in a position where we can and should present a cleaner and more complete picture of root disease-caused losses of forest trees.

1/These data were compiled from estimates and reports submitted by Jim Byler (R-1), Dave Johnson (R-2), Ed Wood (R-3), Jack Marshall (R-4), Gregg DeNitto (R-5), and Jim Hadfield (R-6).

2/Plant Pathology Group Leader, Forest Pest Management, PSW Region, San Francisco, CA.

This report summarizes the volume of wood lost in commercial conifers in which root diseases were a major cause in the tree's death. Trees which are severely weakened by root diseases are often attacked and killed by other pests, such as bark beetles. In these cases we considered that both pests were in part responsible for the tree's death and have included these types of losses in our estimates.

All commercial conifers are attacked by one or more root diseases. The following five root diseases and their causal fungi are responsible for most of the root disease-caused losses in the west:

Annosus root disease caused by Heterobasidion (Fomes) annosum (Fr.) Bref.

Armillaria root rot caused by Armillaria mellea (Vahl. ex Fr.).

Black stain root disease caused by Ceratocystis wageneri Goheen and Cobb.

Brown cubical butt rot caused by Phaeolus schweinitzii (Fr.) Pat.

Laminated root rot caused by Phellinus (Poria) weirii (Murr.) Gilbertson.

Other root diseases can be responsible for small amounts of volume loss on a national basis and may be of local importance. These minor root diseases reported by the Regions are:

Port-Orford-cedar root rot caused by Phytophthora lateralis Tucker and Milbrath.

Red root and butt rot caused by Inonotus tomentosus (Fr.) S.C. Teng.

This report presents the best assessment to date of the annual volume loss of conifers killed by root diseases in the commercial forest land of the western United States.

METHODS

This report is a summary of the best current estimates of root disease losses made by the Forest Pest Management Staff of each of the Forest Service's western Regions, Regions 1 through 6. These reports include all forested areas from the Great Plains westward to the Pacific coast.

Volume losses were reported for all commercial forest lands. Forested lands where logging is not allowed, such as in National Parks, wilderness areas, and other special-use or restricted-use areas, were not included in these estimates. Lands of all ownership were included, and the losses were partitioned into three standard ownership classes:

National Forest lands.

Other federal forest lands.

State and private forest lands.

The volume loss reported includes only the loss resulting from mortality of trees with a measurable volume. Losses of seedlings and saplings which have no volume, but whose losses do affect future productivity, were not included. Losses resulting from reduced growth, wood decay, and areas taken out of production because of root diseases are not included.

The kind and amount of basic loss information available varied from Region to Region and consequently the methods used and the completeness of each estimate differed between Regions. The two basic methods most used were: 1) Direct root disease loss surveys of large areas such as forest types, states, etc., and extrapolation to unsurveyed areas, if needed; and 2) estimating volume loss by multiplying the total tree mortality reported in regional forest surveys by the percent of the total loss due to root diseases found in several smaller or specific surveys of National Forests, counties, forest types, etc. Where information was lacking or inadequate, no estimates of losses were made. The methods used and areas included in the estimate for each Region are contained in the Appendix.

RESULTS

The average annual volume loss in the commercial forest lands of the western United States is estimated to be 237.4 million cubic feet (Table 1). The highest losses were reported from Regions 1, 5, and 6 (California, Idaho, Montana, Oregon, and Washington); the major timber producing areas in the west.

The losses reported are believed to be a conservative estimate, since some Regions, finding the basic data to be lacking or inadequate for certain forest types or ownerships, could not make a meaningful estimate, and hence, submitted no loss data for these units.

The information and estimates submitted by the Regions indicate that true fir, spruce-fir, and Douglas-fir types are the forest types most affected by root diseases and contain the most volume losses due to root diseases.

The annual conifer mortality from all causes in the commercial forest land of the western United States was calculated from data of forest statistics in the United States in 1976.^{3/} The total mortality for lands of all ownerships in the west was listed as follows:

Pacific Northwest -	
Douglas-fir subregion	484,400 M ft ³
Pine subregion	215,200 M ft ³
Pacific Southwest	137,700 M ft ³
Northern Rocky Mountain	294,912 M ft ³
Southern Rocky Mountain	<u>163,649 M ft³</u>
Total	1,295,861 M ft ³

^{3/}An Analysis of the Timber Situation in the United States, 1952-2030, 1982, USDA, Forest Service, Forest Resource Report No. 23. pp. 412-13. Wash. D.C.

Table 1 - The estimated average annual volume loss due to root disease-caused tree mortality in the western United States.

Region	Annual Volume Loss in 1,000 cu. ft.			
	NFS Lands	Other Federal Lands	State & Private Lands	Total All Lands
Region 1 (Montana, North Dakota, Northern Idaho)	54,400	8,200	18,100	80,700
Region 2 (Colorado, Wyoming, Kansas, Nebraska, South Dakota)	127*	**	**	127
Region 3 (Arizona, New Mexico)	2,900	960	890	3,750
Region 4 (Nevada, Utah, Southern Idaho)	1,400	75	140	1,615
Region 5 (California, Hawaii)	12,282	396	6,695	19,373
Region 6 (Oregon, Washington)	51,453	14,916	65,562	131,931
TOTAL				237,431

* A partial estimate for one forest type only.

** Insufficient data available to make an estimate.

Using estimates of root disease-caused losses reported by the western Regions and the latest estimates of total softwood mortality from all causes as reported for the western United States for the same area, root diseases are responsible for approximately 18 percent of the softwood mortality in the commercial forests of the western United States.

$$\text{Root disease-caused mortality} = \frac{237,431 \text{ M ft}^3}{1,295,861 \text{ M ft}^3} = 18\%$$

The narratives provided by the western Regions indicate that their estimates were conservative and that root disease-caused mortality is increasing. Thus we can expect that the actual volume lost and the percentage of total mortality from root disease will increase in future years.

DESCRIPTION OF ROOT DISEASES

The important root diseases of forest trees in the western United States are all caused by fungi. In this section the following major root diseases, their causes, hosts, geographic range, and effects are described:

Annosus root disease;
Armillaria root rot;
Black stain root disease;
Brown cubical butt rot;
Laminated root rot.

Annosus Root Disease - Annosus root disease, caused by the fungus Heterobasidion (Fomes) annosum, attacks all western conifers. Infection centers are started when spores of the fungus land on freshly cut stumps or basal wounds of live trees and the fungus colonizes the stump, butt, and root system. The fungus spreads from the infested root system to adjacent trees via root contacts (Fig. 1). This new host is eventually killed and new sporophores (conks) are produced within the rotten stump or on or under the bark at the root crown.

Resinous conifers, like pines, are girdled by the fungal invasion of the cambium and sapwood at the root crown and the tree dies. Bark beetles, Dendroctonus spp., and pine engravers, Ips. spp., often attack and kill the dying pines. In non-resinous conifers, such as true firs and spruce, this fungus kills the smaller roots and rots the heartwood of the larger roots and the butt. Affected trees may die quickly or gradually decline over a period of years (10 to 20). Infected true firs are often killed by the fir engraver, Scolytus ventralis LeConte, or the flatheaded fir borer, Melanophila drummondi Kirby, or are windthrown.

Annosus root disease is important in the pine forests of eastern Oregon and California, in the true fir, and spruce-fir forests in all western states, and in the hemlock forests of Oregon and Washington (Fig. 2). As stand management activities increase, we can expect the incidence of annosus root disease to increase. Stand management activities which wound the roots and root crowns of fir, spruce, and hemlock increase the incidence of and damage by this disease. The presence of untreated stumps left after harvest increases the incidence of the disease. Overstocking and/or poor site can aggravate this problem in true fir.

Because of the direct correlation between forest management activities and incidence of annosus root disease, we can expect losses caused by this disease to increase in the future as we intensify our forest management. This would follow the pattern of annosus root disease incidence seen in Europe and in the southeastern United States.

Armillaria Root Rot - Armillaria root rot, also called shoestring root rot, is caused by the fungus, Armillaria mellea. This fungus attacks many woody plants, including coniferous and hardwood trees.



Figure 1 - Infection center of Heterobasidion annosum in the eastside pine type, Lassen National Forest, California. The fungus most likely became established in the stump, grew through the roots, and attacked surrounding Jeffrey pines. The declining Jeffrey pine at photo center will probably be killed by bark beetles in 1-2 years.



Figure 2 - Heterobasidion annosum causes mortality, windthrow, stem breakage and butt rot of true firs. The fungus will persist for many years and interfere with the survival of true fir regeneration.

Infection centers are started when the roots of a tree come in contact with an infested root of a previously infected host, or when a lightly infected tree is injured to the point that it loses its ability to resist the fungus. The fungus spreads from this infected root system to adjacent trees via root contacts or by rhizomorphs, root-like fungus structures which grow through the upper soil layers to infect the roots and root crowns of adjacent trees.

The fungus penetrates the bark and attacks and kills the cambium and sapwood of the roots and root crown. At the root crown the fungus girdles the tree and the tree dies or is attacked by bark beetles, engraver beetles, or wood borers. The fungus also decays the roots. Where the advance of the fungus through the cambium is slow, the fungus may cause sufficient root decay to make the tree more susceptible to other pests and windthrow.

The significance and role of this root disease varies between Regions, forest types, tree species and age, and stand and site conditions. This fungus is often seen acting as a saprophyte but at other times it is an aggressive pathogen. The role this fungus plays appears to be the result of the following interacting variables: The virulence of the particular isolate of the fungus involved; the susceptibility of the host which varies according to species, age, and vigor (health); and the amount of energy (food base) available to the fungus when it is attacking the new host. The result of these interactions may explain the variation seen in the damage caused by A. mellea under varying conditions.

This fungus and disease are widespread throughout the forests of the West. It is found in most forest types but with differing effects. It appears to be most damaging in young conifer stands, in stands where other pests have weakened the trees, and in some forest types when partially cut (Fig. 3, 4).

This disease disrupts normal management practices by restricting the use of intermediate cuts, some harvest cutting methods, and the use of some tree species. It can result in increased management costs and decreased productivity.

Black Stain Root Disease - Black stain root disease is caused by the fungus Ceratocystis (Verticicladiella) wageneri. This disease attacks the roots and root crown of Douglas-fir, hemlock, and pines, causing a black to dark brown stain to develop in the sapwood of infected roots and stems. This vascular wilt type of disease causes a rapid decline and death of the infected tree. Bark and engraver beetles may attack and kill the infected tree in the later stages of decline. The fungus dies in the host tissue soon after the tree dies.

Long distance spread probably involves a vector, such as a bark beetle or a weevil. Short distance spread occurs from tree to tree via root grafts or contacts.

This disease was first found in ponderosa pine stands and pinyon pine stands of California, Colorado, and New Mexico, but currently is found more often in young (10-30 year) sapling and pole-sized stands of Douglas-fir. This disease can be of local importance in Douglas-fir, ponderosa, Jeffrey, and pinyon pines in Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, and Washington.

This disease appears to be most common in young, overstocked, almost pure (one species) stands which have been disturbed by man. The fact that many of our future stands will be young, disturbed, and perhaps overstocked suggests that this disease will increase as forest management increases. However, the lack of information about the long distance spread and the identity of the vector makes such a conclusion conjectural. Until research provides us with these answers or our experience more strongly indicates a trend, we cannot make any strong predictions about the future importance of this disease.

Brown Cubical Butt Rot - Brown cubical butt rot, caused by the fungus Phaelous (Polyporus) schweinitzii, attacks the roots of Douglas-fir, pines, spruce, and larch, particularly those with fire scars. It is especially



Figure 3 - A large Armillaria root disease center in western Montana. After the original stand was killed by Armillaria mellea and fell over, the area seeded into Douglas-fir. The young stand seen in this view is being killed by this root disease before it reaches commercial size. Thus, the land is made unproductive.



Figure 4 - The edge of a large Armillaria root disease center in western Montana showing the dead trees at the margin of the center. The live trees next to the dead ones are most likely already infected by this disease.

prevalent in old-growth Douglas-fir. This fungus can persist in the roots of dead or cut trees and infect the roots of young trees in the succeeding stand. Characteristic conks are formed on or near the base of infected trees or stumps. These release spores which infect other trees.

The effects of this disease are the occasional death of young trees, decay of root and butt heartwood in older trees resulting in windthrow, and predisposition to other pests, including bark beetles and A. mellea.

Brown cubical butt rot is most important in the Douglas-fir and mixed conifer types of California, Oregon, Washington, Idaho, and Montana.

Careless silvicultural operations which wound residual trees increase the risk of future damage from this disease. Shorter rotations and less old growth timber should result in less damage in the future.

Laminated Root Rot - Laminated root rot, caused by the fungus Phellinus (Poria) weirii, attacks most western conifers. Douglas-fir, the hemlocks, true firs, and spruces are highly to moderately susceptible; and pines, western redcedar, larch, and incense-cedar are tolerant to resistant. The fungus survives for decades in large, old infected stumps and roots in the soil. New hosts are infected when their roots contact these old infested roots. The fungus spreads from infected trees to adjacent trees via root grafts and contacts. This disease causes growth loss, butt decay, uprooting and windthrow, and tree mortality. Douglas-fir bark beetle, Dendroctonus pseudotsugae Hopk., and the fir engraver Scolytus ventralis LeConte, are commonly associated with this root disease.

It is not known how long distance spread occurs and how new infection centers are established.

This disease is found throughout the ranges of Douglas-fir and true fir in Oregon and Washington and approximately the range of grand fir in northern Idaho and western Montana.

Annual losses due to the laminated root rot in the Douglas-fir type west of the Cascades is estimated to be 32 million cubic feet. It also causes severe volume losses in Douglas-fir, mountain hemlock, white fir, and grand fir east of the Cascades in Oregon, Washington, northern Idaho, and Montana.

This root disease limits the alternatives available to the land manager. It restricts his choice of tree species to use in regeneration to those which are tolerant or resistant. It restricts the use of certain silvicultural practices, such as shelterwood cutting which favors the regeneration of tolerant species, most of which are moderately to highly susceptible.

MANAGEMENT IMPLICATIONS

Forest pests and the losses they cause affect forest management practices in several ways. They lower production, increase costs, change vegetation, disrupt plans, and necessitate special pest management practices. Root

diseases are especially difficult pests for management to deal with. They attack the roots and are not visible; hence, the early stages are not readily detectable. Being on the roots in the ground they are not easily reached for control treatments. They often live for decades in old infected roots and stumps in the ground and threaten future forests with continued losses. The history of other forested regions of the world indicate that these root disease-caused losses increase as forest management becomes more intense, suggesting that we can expect our losses, due to root diseases, to increase. The current and projected future levels of root disease losses will have significant effects on future stand management. With our current information we have attempted to describe these management effects.

Root disease-caused losses decrease Regional and National timber production - Current losses due to root diseases are significant and may become even greater in the future. These losses often are not adequately considered in estimates of future forest yields and could adversely affect attainment of Regional and National timber targets. Besides causing direct volume losses, root diseases may cause additional indirect losses which can also affect forest yields. Root diseases may prevent regeneration and keep lands out of production for decades; they may reduce the yields and increase the costs of management so that lands are not economically manageable and must be withdrawn from production; and they may cause a change in silvicultural prescriptions and management plans which result in decreased production from the land. Some of these effects and their magnitude are known while other effects are inferred from observations and from the experiences of other forest areas. These will remain undefineable until research or experience yields additional information.

Root diseases could increase production costs of timber management and limit the available management options - Root disease prevention and control actions such as stump treatment, sanitation-salvage cuts, use of alternate species, special site preparation procedures, additional stand examinations, special local stand plans and treatments, etc., result in higher production costs. Certain stand management options may become unacceptable because of these associated increased costs and/or decreased yields.

Root diseases affect resources other than timber management - Recreation values and costs are adversely affected by these root diseases which kill trees, resulting in the loss of desirable vegetation, and weaken trees, causing them to fail and damage property and injure people. Some recreation sites have been abandoned or had their primary use changed because of root disease effects (Fig. 5). Visual quality is sometimes degraded when clearcuts become necessary to control or prevent continued chronic root disease losses. Wildlife is affected by the openings created in older stands. These openings may favor browsing animals such as deer which feed on the new brush, but they are also harmful to those animals, such as eagles and spotted owls, which require an old growth habitat. In some areas root disease killed trees have provided a continuous supply of firewood to the local residents. Root diseases may also result in an undesirable build-up of fuels in affected stands and increase fire hazard.



Figure 5 - Root-rotted trees can be windthrown and cause damage to property and hazard to human safety in developed recreation and public use areas. This incense-cedar and ponderosa pine, both infected by Heterobasidion annosum, were blown over during a winter storm in Yosemite National Park.

Root diseases affect other pests and pest-caused losses - Root diseased trees continually provide a desirable habitat for bark beetles, flatheaded borers, and engraver beetles which help maintain higher populations of these pests. This results in more frequent and more damaging insect outbreaks.

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APPENDIX

Comments by Individual Regions on Root Disease Losses

REGION 1 ROOT DISEASE LOSS ESTIMATES

The estimate of 80.7 million cubic feet annual volume loss is based on the assumption that about 30 percent of the Region's total endemic mortality is due to root disease (Byler 82). Root disease surveys on the Clearwater and Nezperce National Forests indicate that about a third of the mortality was due to root disease and observations suggest losses there are not higher than in most other parts of the Region.

Acreage infested may be a better measure of damage than is volume loss since volume loss does not account for acreage out of production, or reduced productivity caused by the death of submerchantable trees. Surveys on seven of the Region's most productive National Forests suggest that at least 75,000 acres (one percent of the commercial forest land) are occupied by root disease centers which were discernible on aerial photographs. These centers are small (one-tenth acre or less) to large (100 acres or more) openings in the stand where most or all of the overstory trees have been killed. Many centers have seeded in to susceptible species and regeneration is also being killed; others are brush fields.

Many stands have varying amounts of scattered individual tree mortality. Of these, an estimated 1.2 million acres (16 percent of the commercial forest land on the seven National Forests) have scattered root disease killing of one or more merchantable-sized trees per acre. Root disease is a major management consideration on these acres because of reduced management options. Armillaria mellea or Phellinus weirii are associated with most of the scattered mortality, and most of the root disease centers.

An additional large unestimated acreage is occupied by stands that are severely affected with brown cubical root and butt rot caused by P. schweinitzii. Considerable volume loss occurs from decay in mature Douglas-fir stands. This disease contributes to mortality indirectly by predisposing the trees to windthrow, Douglas-fir beetle, or Armillaria root rot.

Extrapolations from the surveys on the seven National Forests suggest that root disease is an important management consideration on about 3.3 million acres of Region 1 land of all ownerships. This estimate includes stands with disease centers and scattered mortality, and amounts to about 15 percent of the Region's commercial forest land. Most of the damage occurs in Douglas-fir and true fir stands of northern Idaho and western Montana.

Foresters are becoming increasingly aware of the root disease problem and have begun to alter timber stand prescriptions because of it. Treatments most often prescribed because of root disease include clearcutting infested stands rather than partial cutting, regenerating with less susceptible species after

harvesting the Douglas-fir and grand fir, and precommercial thinning to favor less susceptible species. Some treatments are considerably more expensive than those that would otherwise be prescribed. For example, planting less susceptible species costs \$200 per acre more than natural regeneration with Douglas-fir. The economics of such treatments are sometimes uncertain because loss projections following different treatments have not been well quantified.

REGION 2 ROOT DISEASE LOSS ESTIMATES -

Investigations of root disease losses in the Rocky Mountain Region are in their infancy; therefore, little data are available on volume loss. Although study plots have been established throughout the Region to monitor disease development in various host types, only one study has been initiated to develop loss on a Regional scale. That study included a single National Forest (San Juan) and host type (spruce-fir) (Fuller, in preparation).

Preliminary estimates indicate that of 137,800 dead subalpine fir (Abies lasiocarpa) evaluated on the San Juan National Forest, 1.3 percent had root disease, primarily Armillaria mellea. These trees were scattered over the entire spruce-fir type of 363,300 acres. The area containing root disease was estimated at 38,400 acres or 10.6 percent of the type. Associated volume loss of subalpine fir was estimated and is presented below:

	<u>Annual Volume Loss (Cu.Ft.)</u>
NFS lands	29,000
Other Federal	---
State and Private	<u>700</u>
TOTAL	29,700

Volume loss for the entire Rocky Mountain Region for National Forest lands is not available since tree volume differs greatly from the southern to northern half of the Region; however, if we only project one-half the volume loss estimated for the San Juan National Forest for the entire spruce-fir type (National Forest Lands) in the Region (3,106,200 acres CFL), annual losses would probably exceed 127,000 cubic feet. The loss is only in subalpine fir; however, this species appears to be more susceptible to A. mellea than spruce. Because of this, the study was confined to fir on the San Juan National Forest. Also, this Forest harvests more fir than the other Forests in the Region and is more concerned about losses.

REGION 3 ROOT DISEASE LOSS ESTIMATES -

The root disease loss estimates for the Southwestern Region are based upon the results of a Region-wide mortality survey of the commercial timber types of six National Forests. The results of this survey indicate that root diseases and associated pests are responsible for about 34 percent (79,235) of the trees killed, and about 30 percent (9.7 million board feet) of the volume lost on an annual basis. For a number of reasons, we consider the estimate of

dead trees to be much lower than the actual number which died. Volume loss estimates are probably more accurate, but are certainly lower than the total volume lost. Losses not measured include trees smaller than 5 inches dbh, growth losses which occur either prior to tree death or which result from sublethal agents acting overtime, and area out of production as a result of persistent root disease agents.

Shoestring and annosus root rots together accounted for essentially all of the mortality attributed to root diseases. Black stain root disease and brown cubical rot have been identified on commercial tree species in Region 3, but so far, no attempt has been made to estimate their impacts.

A larger proportion of the mortality sampled was attributed to these pests in mixed conifer and spruce-fir stands than in ponderosa pine stands. Shoestring root rot was associated with the death of about 78 percent of the root-diseased trees, containing about 80 percent of the volume lost; annosus root rot was found in the remainder.

REGION 4 ROOT DISEASE LOSS ESTIMATES -

Region 4 loss estimates are probably very conservative. Stand surveys have gathered information on root disease incidence and attributable volume loss (mortality); however, Region-wide knowledge is lacking for overall incidence, associations with other pest organisms, specific site associations, and impacts. What we do know, or what we have conservatively extrapolated from individual stand surveys, is presented in this report.

A total loss estimate represents both direct and indirect volume loss associated with major root/butt disease organisms. Direct losses include butt log cull, loss of anticipated incremental growth, windthrow, and mortality. Indirect losses involve root disease-stressed trees subsequently attacked and killed by various bark beetles.

Not included in the total loss estimates are the loss of future stands from mortality in plantations and areas out of production due to resident root disease organisms. Although individual mortality centers representing areas out of production may be relatively small (i.e., Annosus root disease centers in pine plantations may average only 0.005 acres in size), loss of potential volume from these sites may be considerable on a Region-wide basis.

REGION 5 ROOT DISEASE LOSS ESTIMATES -

Root diseases cause several types of losses in timber management. The figures presented estimate mortality, which may or may not represent loss depending on the amount of salvage that takes place. Even when salvaged, though, some loss occurs because of tree death prior to the time of optimum productivity. Two other losses are not presented in mortality estimates. Prior to mortality, infected trees may undergo some growth reduction below optimum projections. Following tree mortality, two root diseases (annosus and Armillaria root diseases) in Region 5 continue to cause reduced site productivity because of their persistence in butt and root systems and their

ability to infect and kill regeneration for an extended period of time. Therefore, total losses, or more accurately, reduced productivity, are greater than that which is shown.

Mortality involving root diseases fluctuates yearly. Recent surveys indicate this fluctuation can range from over 1.5 million to 34.5 million cubic feet. The principal agent influencing this fluctuation is the amount of available soil moisture, primarily as a result of precipitation. Root disease-related mortality during the first year of a drought increases above average levels. As the drought continues, the proportion of the mortality that involves root diseases decreases. After precipitation returns to normal levels, the amount of root disease-related mortality declines to its lowest levels. This is probably a reflection of the improved health of the forest and the previous death of many of the root-diseased trees.

The fluctuation in mortality is not a reflection of changes in the incidence of root diseases in the forest. Over the short run, the incidence of root diseases will remain rather constant over large areas. Estimating this incidence requires determining how much land area an infected tree or stump occupies. At this time, this type of information is not available. Instead, an attempt has been made to estimate the acres where root diseases may or could interfere with management objectives. This is based on forest types where the presence of root disease has required alterations in management options and possible implementation of control techniques. An estimated 8,132,000 acres of commercial forest land in this region are adversely impacted by root diseases. These acres are distributed among ownership classes as follows:

NFS -----	4,290,000 acres
Other Federal -----	193,000 acres
State & Private -----	3,649,000 acres

Root disease-related mortality estimates on NFS lands were derived from four sources. Three recent Forest-wide mortality surveys provided estimates of root disease-related losses per acre. Acres of commercial forest land (cfl) by National Forest were obtained from Bolsinger (1980). The per acre estimates were expanded to a cfl basis for the respective Forests and for surrounding Forests. For Forests where this information was not applicable, it was assumed that 15 percent of the annual mortality reported by Bolsinger (1980) was root disease-related. Estimates on non-National Forest cfl were derived from the acreage of cfl for each county and the appropriate per acre factor from the nearest surveyed Forest or 15 percent of the reported mortality from the nearest National Forest. The estimates fall within the range of root disease-related mortality estimates obtained from statewide surveys of cfl during and following the 1975-77 drought.

The area of management concern is based on our perception of which forest types in the State are impacted by root disease. These are eastside pine, mixed conifer, white fir, and red fir. For NFS lands, the acreage estimate of cfl in these types was determined by the Timber Management Staff. For non-NFS lands, the estimates were obtained by county from forest type maps and partitions made in certain counties for other Federal and state and private lands.

REGION 6 ROOT DISEASE LOSS ESTIMATES -

Root diseases have to be considered one of the most serious threats to the timber resource of the Pacific Northwest Region because of the magnitude of losses and difficulty of treatment. All commercially important tree species are affected, some, such as the genus Abies, much more than others.

Loss data by tree species groups are generally lacking. However, we estimate that approximately five percent of the Douglas-fir and true fir types are out of maximum production because of root pathogen infestations. Root diseases are thought to annually kill 0.1 percent of the volume of white and grand fir.

Effects of root diseases on setting and meeting timber targets are difficult to assess. Some, but by no means all, of the volume losses are built into projected timber yields. The acres of successfully established plantations are lowered because of root diseases.

Root diseases can drastically alter routine stand management. If the diseases are ignored, yield can be reduced as much as 60 percent from potential. The most frequent management response to root diseases is to favor tree species less susceptible to the pathogen(s) present. In many cases, this means substituting a less valuable tree species or a species not as well suited ecologically as the preferred species. Root diseases can negate the effects of precommercial thinning and alter preferred stocking levels. They can influence rotation ages usually by shortening them.

Root diseases can indirectly affect management of stands for game habitat, especially by game such as deer and elk. These animals require hiding and thermal cover. Douglas-fir and true firs provide both, but are frequently damaged by root diseases east of the Cascades. Tree species less desirable may have to be substituted.

Trees in developed recreation sites can be severely weakened by root diseases, thus increasing their failure potential. Statistics on tree failures in the Pacific Northwest reveal that root rots and disease were the cause of tree failure for 42 percent of the trees.

The importance of root diseases is increasing in Region 6. The incidence of damage is increasing as is the volume loss.

Costs of direct control are high (\$300-500/acre), but, in some cases, there is no alternative other than ignoring the disease.

Foresters are just beginning to become aware of how serious root diseases are. Many feel this class of diseases is the biggest obstacle they face to successful forest management.